Learning through Arduino Projects: Does Gender Matter?

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Abstract: The focus of this paper is on using the Arduino as an educational tool and encouraging equal participation of women in the ICT filed. The purpose is to contribute to the understanding of gender differences in working and learning on Arduino projects. The target population consists of first-year undergraduate students of Informatics where male students outnumber female students. Consequently, the sample consists of 44 students, 75% male and 25% female. The Arduino platform was used in an introductory course in information science. During 15 hours of computer lab lessons, students had to make five Arduino projects working in teams, supervised by a teacher and a peer-mentor. Learning through Arduino projects contributes to a better understanding of interactions between hardware, software and real-world systems, which is of fundamental importance for future ICT specialists. Based on the conducted research, statistically significant differences between gender were confirmed in student self-assessment of work on Arduino projects considering teamwork, learning and use of Arduino. Female students are more likely to be more frustrated with the work on Arduino projects, work with Arduino hardware, consider their involvement in teamwork less important, and share less of their knowledge within the team. However, through peer and active learning, working on Arduino projects supervised by the teacher, all the students acquired useful knowledge, got a deeper understanding of the course topics and improved their problem-solving skills.

Keywords: Arduino, STEM, ICT, Gender Gap, Gender Stereotype, Peer Learning

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Introduction

This paper reports about using Arduino for students' projects on an introductory ICT course where self-assessment of learning through Arduino projects is researched. The aim of the research is to determine whether there are gender differences in the self-assessment of learning with Arduino. The purpose of this paper is to contribute to the understanding of gender gap in ICT.

The Arduino platform is suitable for educational usage because it is open-source hardware, adaptable, easy to use, cheap, has a user-friendly development environment, and there are many resources available for teachers and students. The Arduino helps students develop STEM knowledge, problem solving skills and acquire

competencies that will play an important role in future jobs driven by robotics, Internet of things, machine learning, artificial intelligence and other emerging technologies. A lot of effort is being put in worldwide to support girls to code and make with the Arduino platform. The goal mentioned in the Arduino User Group manifesto is to build a global network of communities that will co-design projects, exchange ideas, organize collaborative activities, and teach official Arduino courses — regardless of age, gender, language and technical ability. “Being inclusive is at the core of our mission: making technology easy to use, we want to empower everybody to be free to innovate.” (https://www.arduino.cc/en/aug/). Analyzing the Arduino community, gender is not a big part of its online identity in Arduino Forums, and gender was left entirely out of user profiles on the Arduino Forum (Buckley, 2017). Despite that, men created the majority of traditional Arduino projects posted on Vimeo, YouTube, Flickr and other websites (Guzzetti & Lesley, 2016: 277).

Learning about and with modern technology, as well as the adoption of that technology, should be gender neutral, but in practice this is not the case. Long-standing gender stereotypes distance female students away from STEM, making gender disparities prevalent in STEM fields (Bal, 2022; Nozava & Regt, 2020; Punzalan, 2022; Ruttenberg-Rozen, Hynes, & Mamolo, 2022). These stereotypes, and lack of digital self-confidence by women, are the biggest obstacle to gender equality in ICT (EIGE, 2017). Girls are less confident in their maths, science and IT abilities than boys, which leads to girls’ lower engagement in science and ICT (Ramos et al., 2018). According to the UNESCO research, girls lose interest in STEM subjects with age, starting with lower levels of participation at secondary school, continuing in higher education, where only 35% of STEM students are women, and only 3% of female students choosing information and communication technologies studies (Nozava & Regt, 2020). These lead to the insufficient representation of girls and women in STEM and ICT in higher education. A research conducted on more than 2000 pre-university and university students in United Kingdom shows that the gender gap in STEM begins at school where fewer and fewer girls are learning STEM subjects, and continues at work and career, as shown in Figure 1 (Andrews et al., 2017).

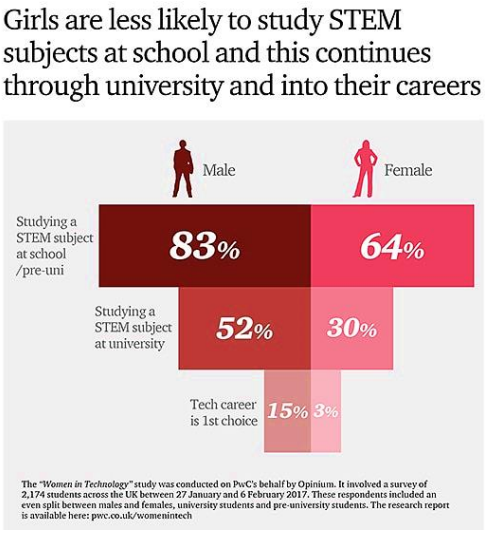

Figure 1. Male vs Female in STEM at School and Work

Source: https://www.pwc.co.uk/who-we-are/women-in-technology/time-to-close-the-gender-gap.html

Globally, the proportion of women who graduated in ICT related studies is approx. 25% (Ramos et al., 2018). Figure 2 shows countries according to the percentage of women who graduated in ICT related studies (West et al., 2019). A paradox has been observed which indicates that countries with low levels of gender equality (figure 2, red circle) shows the largest percentage of women graduated in ICT, and vice versa (Figure 2, blue circle).

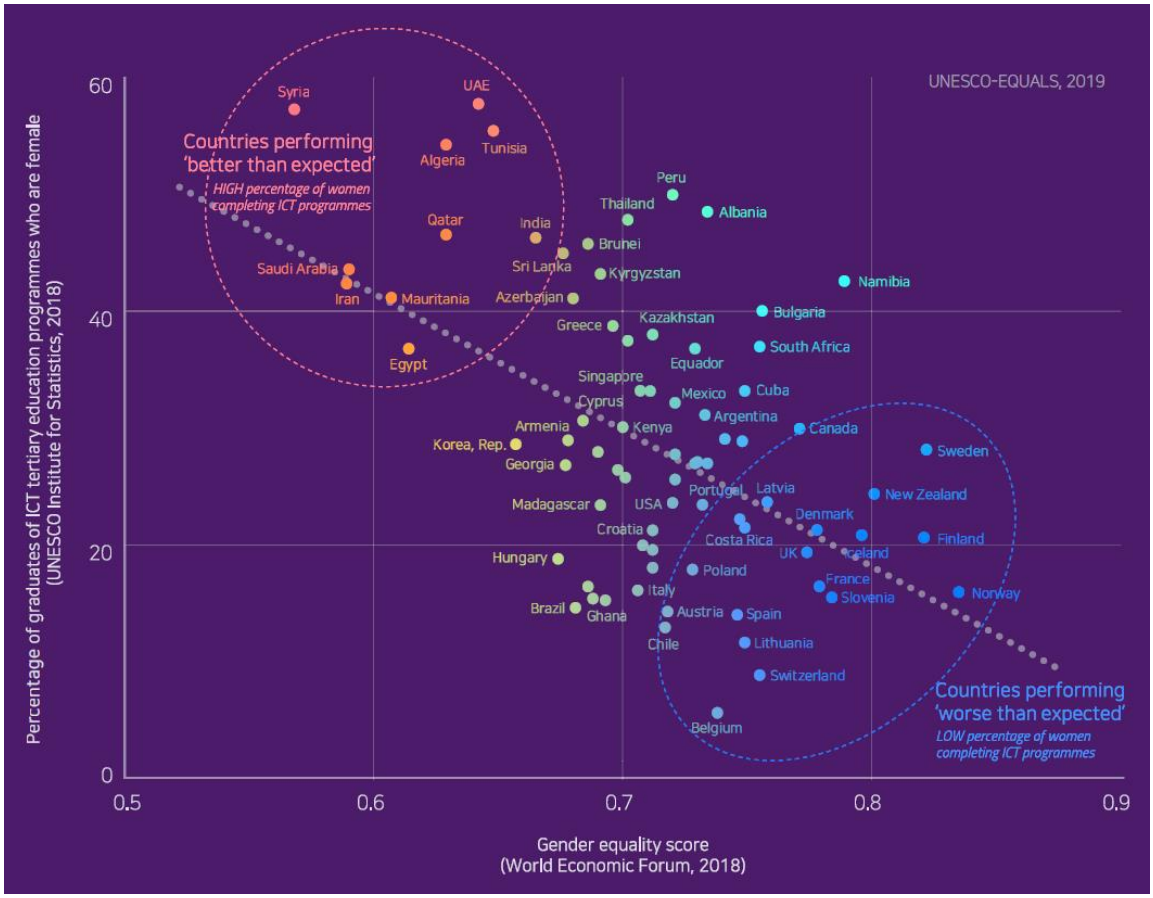

Figure 2. ICT Gender Equality Paradox

Source: https://en.unesco.org/EQUALS/ICT-GE-paradox

Female students usually view themselves as less competent in programming and technical skills, although research shows that gender does not affect programming performance. They find out that the lack of female role models reinforces the perception that a STEM career is not suitable for women (Andrews et al., 2017). Looking at the past, there are only a few famous women in computer science, like Ada Lovelace Byron and Grace Hopper, both the first computer programmers (Dice, 2020). It is a poorly known fact, that at the beginning of development of modern computing, programming was mostly done by women (Ramos et al., 2018).

In most countries of the European Union, share of men in the total number of employed persons with an ICT education is between 70% and 90% (Eurostat, 2021). Only 17% of women in European Union are involved in major technology jobs like programming, systems analysis, or software development, and they make only 20% of the graduates in the ICT degree programs (Sancier-Sultan & Scharf, 2022). Furthermore, the World

Economic Forum (Zahidi, 2021) reports that only 14% of women work in cloud computing, 20% in software engineering, and 32% are data and artificial intelligence professionals. Across major technology companies, female ICT employees are represented from 20% in Microsoft to 23% in Apple, Google and Facebook, while the most influential people are men, like Bill Gates, Steve Jobs, Jeff Bezos, Mark Zuckerberg, Larry Page and Elon Musk (Green, 2021).

Methods

Teaching Methodology

Arduino is recognized as a good educational tool, but the teaching should be pedagogically well-designed. Arduino in education entails project-based learning with a focus on student collaboration, interaction and peer-learning, encouraging problem solving skills and creative thinking. The introductory course of the first-year of the undergraduate study of Informatics used the methodology of project-based learning with Arduino during 15 hours of labs lessons. As future ICT specialists, it is important for students to be familiar with the Arduino platform and its capabilities, which professionals use to solve real-world problems. All teaching materials and other resources have been carefully selected, prepared and uploaded to Moodle. Online learning activities were used to prepare students for classes. Therefore, during the computer labs, students were focused on making an Arduino project. Students worked in teams, and there was at least one female student in each team, due to the greater possibility of peer learning within teams.

There were not only female teams. Each student had their own role in the team (connecting components, writing code, documenting, describing and presenting the project using a systems approach), and with each new project their roles rotated (Krelja Kurelovic at al., 2021). Thus, every student had the opportunity to engage in each team role. They created 5 projects using Arduino RFID kit with Arduino Uno microcontroller board. Each project had its own dynamics and deadlines, as well as evaluation criteria. For the overall success of the project, it was important that students collaborate, share knowledge and take responsibility. Students who had previous experience with Arduino (all male) became peer mentors, which enabled them to apply their knowledge.

Research Methodology

The aim of the research is to determine whether there are gender differences in the self-assessment of the learning through Arduino projects. In order to fulfill the research objective, a questionnaire was created with 8 question items grouped in 4 categories: general (demographic data), teamwork, learning, and using Arduino. Each question item used Likert-type scale responses (5=strongly agree, 1=strongly disagree). At the end of semester, students were asked to complete an anonymous online questionnaire available on Moodle.

The research sample consists of 44 students (at the age of 18-21) who completely filled out the questionnaires, 33 male (75%) and 11 are female (25%) students. Sample represents 71% of all students enrolled in the course.

In accordance with the aim of the research, the following null hypothesis is proposed: There is no significant difference between gender in the self-assessment of learning through Arduino projects considering:

- teamwork (H1.1),
- learning (H1.2),
- use of Arduino (H1.3).

A t-test for two independent samples was used for testing the hypothesis (its three parts).

Results and Discussion

By monitoring the number of students who enrolled in the 1st year of study of Informatics (ICT) at the Polytechnic of Rijeka, a higher proportion of male students (77% - 81%) compared to female students (19% - 23%) can be observed over years (table 1). In this case, the proportion of female students studying ICT is lower than reported by some authors (Nozava & Regt, 2020; Andrews et al., 2017), but it is higher than the European Union average of 17% (Eurostat, 2020).

Table 1. Number of Students in the 1st Year of Study of Informatics by Gender

Academic Year	Num of students	Male	Female
2021/22.	95	77 *(81.05%)*	18 *(18.95%)*
2020/21.	74	59 *(79.73%)*	15 *(20.27%)*
2019/20.	62	48 *(77.42%)*	14 *(22.58%)*
2018/19.	54	43 *(79.63%)*	11 *(20.37%)*
2017/18.	58	45 *(77.58%)*	13 *(22.41%)*

The descriptive statistics of research questions are presented in table 2. With regard to the comparison of mean values, male students have higher values on all questions then female students. A higher score indicates a greater degree of agreement with the statements. The highest score in self-assessment, male students expressed for assembling the Arduino and team contribution, while female students for a better understanding of the course topics. The biggest differences in mean values by gender were observed in assembling Arduino components and improvement of problem-solving skills, while female students expressed a much higher level of frustration with Arduino projects. By testing the hypothesis, it will be determined whether the mentioned differences are statistically significant.

The reason why there is no questionnaire item about programming is that the Informatics major has several programming courses. In this case, students were allowed to use ready-made programming codes from the Arduino community or GitHub. Therefore, they just had to adjust those codes for each project, which means that an understanding of programming was required.

Table 2. Descriptive Statistics of Responses to the Questionnaire

Self-assessment items	Male (N=33)		Female (N=11)	
	Mean	SD	Mean	SD
Teamwork:				
I consider my contribution in teamwork on Arduino projects important.	3.9	0.91	3.27	0.91
I shared my knowledge with teammates and encourage the team members.	3.88	0.86	3.18	0.75
Learning:				
I gained a better understanding of the course topics (ICT and basic of electronics).	3.61	1.04	3.27	0.65
I have improved my problem-solving skills needed to complete teaching assignments.	3.73	1.09	3.00	0.77
Use of Arduino:				
I felt confident while assembling the Arduino components.	3.97	1.03	3.09	1.14
Working on Arduino projects did not frustrate me.	3.64	1.10	2.91	0.94
Total	3.79	1.01	3.12	0.85

Teamwork and gender

Cooperation and teamwork are necessary in many activities and today's workplaces, especially in the ICT field. Therefore, it is important to create opportunities for students to develop such skills during their education. The 33 male students (M=7.79, SD=1.63) compared to the 11 female students (M=6.45, SD=1.51) demonstrated significantly better results in the self-assessment of their engagement in teamwork on Arduino projects, as confirmed by a two-tailed t-test, t(43)=2.39, p=0.02. With a confidence level of 95%, we can reject the null hypothesis H1.1.

Learning and gender

Learning through Arduino projects contributes to a better understanding of interactions between hardware, software and real-world systems, develops problem-solving skills, which is important for an ICT career. In the self-assessment of learning on Arduino projects male students *(M=7.33, SD=1.46)* show better results than female students *(M=6.27, SD=1.10)*, which is confirmed by a two-tailed t-test, *t(43)=2.19, p=0.03*. Accordingly, we can reject the null hypothesis H1.2. with the 95% of confidence. It can be concluded that the male students benefited more from learning by doing Arduino projects. Although more detailed research would be needed to understand such a result, many authors (EIGE, 2017; Ramos et al., 2018; Nozava & Regt, 2020) believe that gender stereotypes represent a major obstacle to gender equality in ICT.

Use of Arduino and Gender

Regarding the use of Arduino, the results of students' self-assessment show that men (M=7.61, SD=1.64) have better results than women (M=6.00, SD=1.48), and these differences are statistically significant, t(43)=2.88, p=0.00. Consequently, the null hypothesis H1.3. is rejected, and we can conclude that male students were significantly less frustrated and had more confidence in doing Arduino projects. These findings correspond to the research results of other authors (Andrews et al., 2017; EIGE, 2017; Ramos et al., 2018).

Conclusion

Although digital competences are becoming more important in digital age, gender disparities still exist in ICT fields, from education to employment. There are many studies, as well as educational, social, cultural, political and other activities, that try to reduce the gender gap in the digital world, but mostly the results are missing. The relatively low percentage of women's enrolment in STEM and ICT related studies and occupations suggests that women may face different barriers and stereotypes, as well as lack of self-confidence. It starts at a middle school age, when girls start to lose interest in STEM subjects. Furthermore, girls lack female role models in the world of technology because all of the famous leaders in ICT are men. All these facts indicate that education may play a key role to attracting, motivating and retaining girls in STEM and ICT field.

The Arduino with its "maker" and "do it yourself" (DIY) approach can help students acquire competencies that will play an important role in high-tech jobs. Arduino, as an educational tool, has a lot of potentials, although gender differences in self-assessment of learning with Arduino were found to be significant in this research. It would be interesting to see what results would be if Arduino was used in more courses, because then women would be more familiar with it, and probably less frustrated, with better learning effects.

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